§22. High Resolution Measurements of Time Evolutions and Spatial Profiles of Electric Fields in a Fusion Plasma Neutron Source

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An inertial electrostatic confinement fusion (IECF, see Fig. 1) neutron source is a device injecting ions and electrons towards the spherical center through the hollow cathode, trapping both species in the electrostatic self-field and making fusion reactions in the dense core. An IECF device can be promising for a portable neutron generator as intermediate products along the path to fusion power source. At present, D-D fusion neutrons of about several millions/sec are successfully produced continuously at our research group, and at several institutions, as well.

The most essential objective of our study is to make clear the mechanism of the beam colliding fusion in the IECF device aiming at a significant enhancement of the fusion reaction rate. Recent introduction of equipments for the laser-induced fluorescence (LIF) diagnostics 1) successfully revealed highly localized electric field formation due to space charge associated with spherically converging ions and electrons 2), which had been a key issue to be clarified. Also, we have successfully introduced the LIF method for n = 4 transition of HeI (forbidden transition from 2_1S to n_1D) for a much higher sensitivity.

In this study, we made design refinements of the cathode holdings to operate with a higher voltage, which is effective for a higher neutron yield, and compared the LIF signals in the IECF plasmas at high-voltage and low-voltage operations.

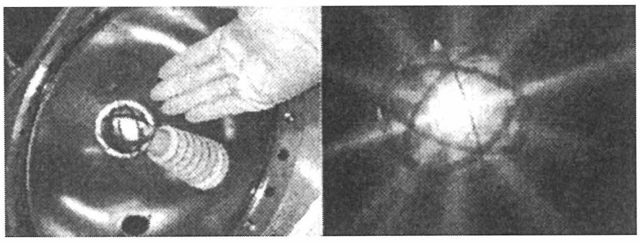


Fig. 1. The hollow cathode at the center of the spherical vacuum chamber as the anode, and an IECF plasma within the hollow cathode

We previously used a ceramics insulator as seen in Fig. 1, which was designed for minimizing asymmetry in the electric field induced by the feedthrough of the cathode. It is found, however, to limit the cathode voltage up to around 25 kV for a helium discharge due to breakdowns by ion charge-up on the ceramics surface. For a higher operating voltage, we removed the ceramics, and used a Ta-tube covered feed through (stainless steel) to minimize sputtering effects. Figure 2 shows cathode voltages as a function of gas pressure at a constant discharge current of 10 mA, comparing the configurations with and without the insulator. It is clearly found that much higher voltages up to 60 kV (the limited voltage of the feedthrough) can be applied without serious breakdown without the insulator.

Figure 3 shows LIF intensities for two different cathode voltages. With a higher voltage applied, both two polarization components of the LIFs are found lower. Since, among the two, $I_y(e_{Lx})$ does not depend on the electric field strength, a lower $I_y(e_{Lx})$ indicates definitely a lower density of metastable He atoms at the 2^1S state. From Fig. 3, $I_y(e_{Lx})$ in the high-voltage operation is found to be approximately one-tenth of that in the low- voltage operation, while the gas pressure, i.e. the density of He atoms, is two-fifths. This fact strongly indicates that the fraction of 2^1S (approx. 20.6 eV above the ground level) state atoms in the high-voltage operation is much smaller due to a smaller fraction of energetic electrons sufficient to excite atoms to the 2^1S state, because of negligible space charge-induced potential.

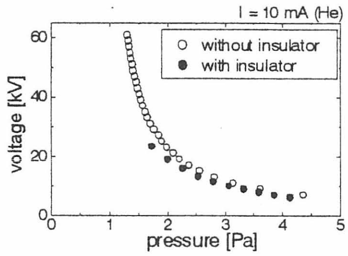
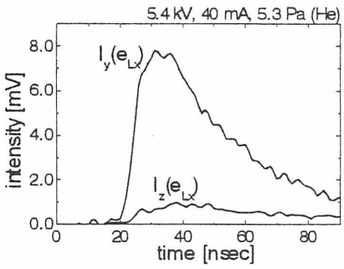
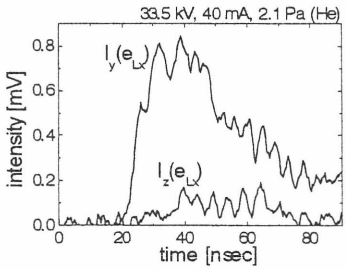


Fig. 2. Voltage vs. pressure, comparing the configurations with and without the insulator



(a)



(b)

Fig. 3. Time evolutions of the LIF intensities for (a)5.4kV, 40mA, 5.3Pa, and (b) 33.5kV, 40mA, 2.1Pa

Reference

1) Takiyama, K., et al.: Jpn. J. Appl. Phys. **25**, (1986) 455
2) Yoshikawa, K., et al., Proc. 18th Symp. on Fusion Energy, Albuquerque, NM,USA, (2000) 27.